Rare Charmless B Decays at CDF

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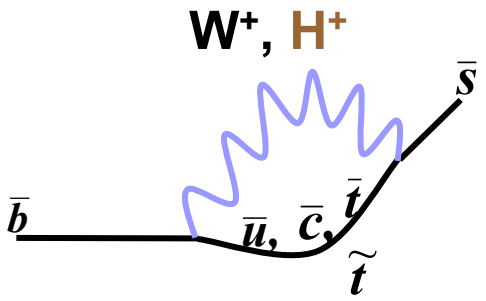
Introduction

- b-quark decays < 2% to charmless modes.

  → Rare: BR < $O(10^{-5})$

- b→sss transitions are penguin dominated
  - Useful to disentangle penguin contribution from other B-hadron decay
  - Particles in the loop can be replaced by their **New Physics** counterparts!
    - Hints in sin2β of $B_d \to \phi K_s$ already?!



- Low longitudinal polarization than expected in $B_d \to \phi K^*$!

- Measure various PV and VV modes and the A_{CP} involved
- Tevatron is a unique place to study the B_s decay modes and add to the present knowledge from B-factories.

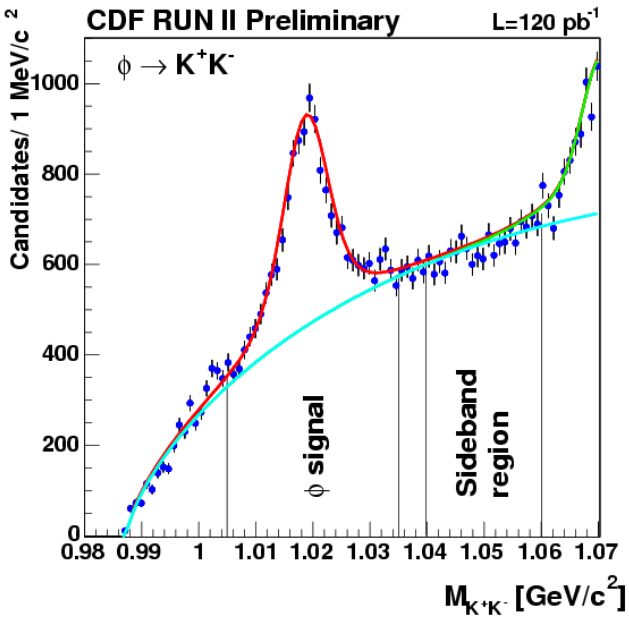
Introduction *continued..*

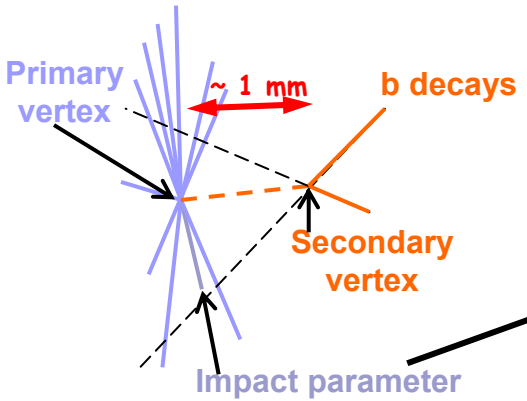
- Tevatron is a rich source of all B-hadron species, B_d, B_u, B_c, B_s and Λ_b
  $\sigma_b = 29.4 \pm 0.6 \pm 6.2$ μb ($|\eta| < 1$) (CDF)
- Currently operates at ~ 10^{32} cm^{-2} sec^{-1}
- CDF Run 2 employs a new track-based hadronic trigger
  → **More rare decay modes accessible**
- Charmless b-decays at CDF w/ displaced tracks trigger
  - $B_u \rightarrow \phi K^{\pm}$ — **Direct A_{CP}**
  - $B_s \rightarrow \phi \phi$ — Mixing & direct A_{CP} (**BR measurement**)
  - $B_{d,s} \rightarrow h^{\pm} h^{\mp}$ ($h = K, \pi$) — Direct only or mixing & direct
  - $\Lambda_b \rightarrow p\ h$ ($h = K, \pi$) — Direct A_{CP} [Talk by Andreas Warburton]
  - $B_{d,s} \rightarrow \mu\ \mu$ — **Search** [Talk in the plenary session]

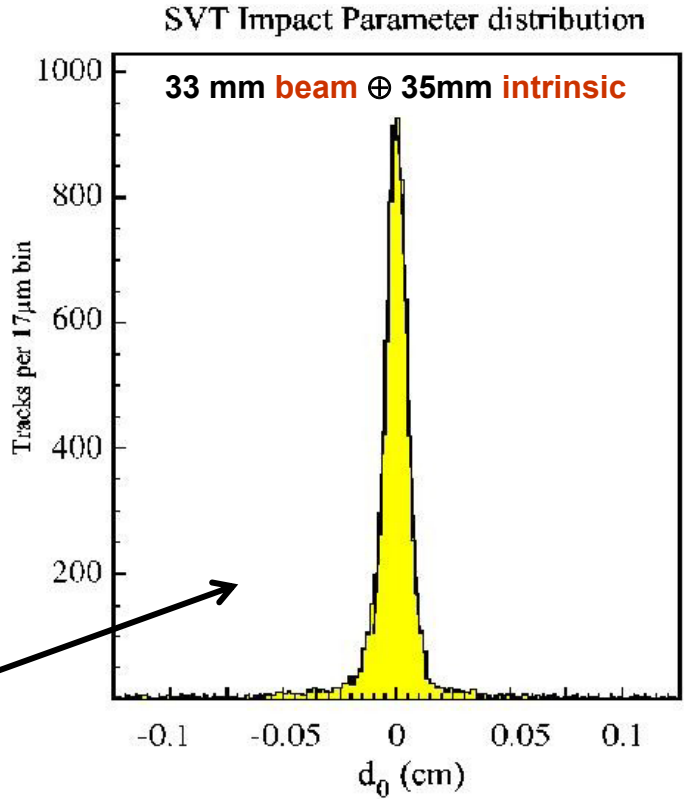
CDF Run 2 Displaced Track Trigger

- Level-1: 2 opposite charged tracks, $P_T \geq 2$ GeV/c
  $\Sigma\ |P_T| > 5.5$ GeV/c
- Level-2: Impact parameter, 120 μm < d_0 < 1 mm
  Transverse decay length, $L_{xy} > 200$ μm
  Azimuthal angle difference, $2° < \Delta\phi < 90°$

ϕ signal from hadronic trigger





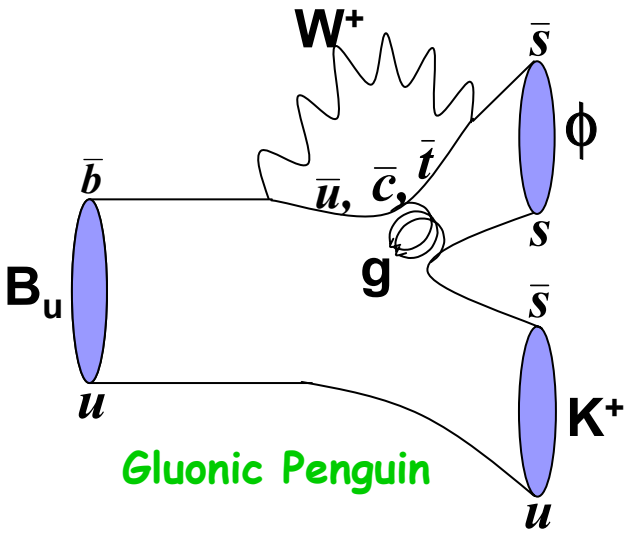


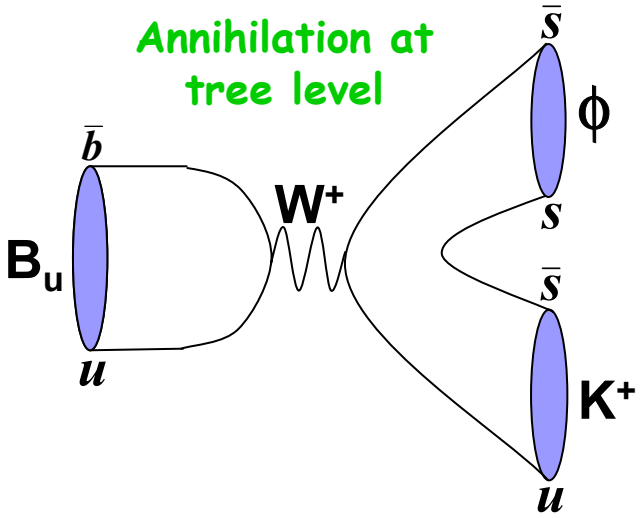
Triggers in use:

- **Baseline trigger**
- **Low P_T:** Drop opp. charge & $\Sigma|P_T|$ requirements
  prescaled, low purity, higher acceptance

$B_u \rightarrow \phi K^{\pm}$ Reconstruction

- EW penguin contribution expected ~10%.
- Small direct A_{CP} expected
- Already established at B-factories
- Potential for New Physics



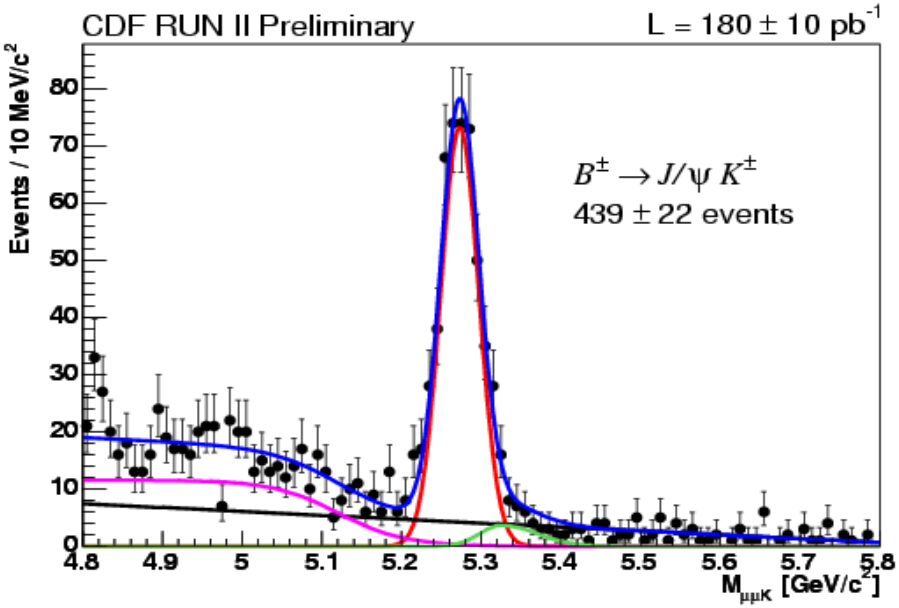


Analysis strategy:

- Use $B_u \rightarrow J/\Psi K^{\pm}$ as control sample.
  - Same event topology, from same trigger
  - Different angular distribution
- Construct a likelihood from kinematic variables and physical background templates derived from MC
- Do an unbinned max. likelihood fit to A_{CP}, signal yield and mass simultaneously
- Use PDG BR($B_u \rightarrow J/\Psi K^{\pm}$) to estimate BR($B_u \rightarrow \phi K^{\pm}$)

$B_u \rightarrow \phi K^{\pm}$ Reconstruction *Continued…*

- Optimized analysis cuts:
  - Lxy > 350mm, Vertex χ^2 < 8
  - P_T^{soft} > 1.3 GeV/c
  - $d_0(B)$ < 100 mm
  - Isolation(R < 1.0) > 0.5
  - 1 < M_{KK} < 1.06GeV/c2
  - 5 < M_{KKK} < 5.6 GeV/c2
  - $\Delta M\mu\mu$ < 100MeV/c2
- Unbinned max. likelihood fit inputs:
  - 2-track invariant mass
  - 3-track invariant mass
  - Helicity angle (ϕ or J/Ψ polarization)
  - Specific ionization in central tracking chamber (dE/dx)



Legends: Total PDF, signal, partially reconstructed decays, combinatorial bkg, physical bkg ($B \rightarrow f_0 K$, $B \rightarrow KKK$, $B \rightarrow K^{*0}\pi$, $B \rightarrow K\pi\pi$)

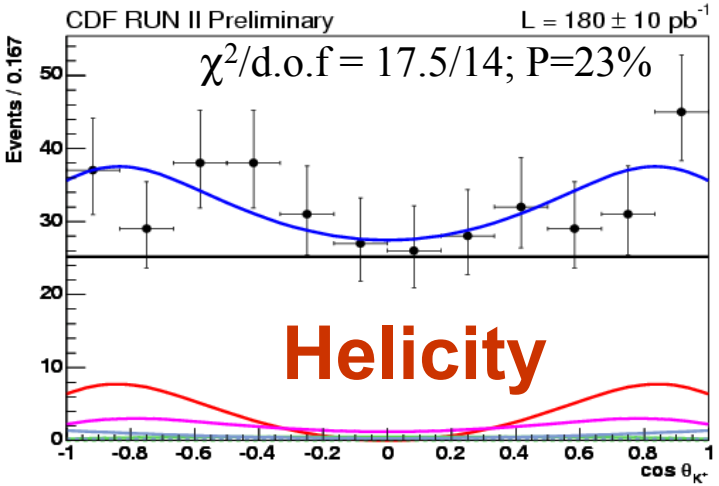
Isolation: $P_T(B)/[P_T(B)+\Sigma_{\Delta R<1} P_T(trk)]$

Helicity angle: cosine of angle between B^0 and one of the ϕ daughters in ϕ rest frame

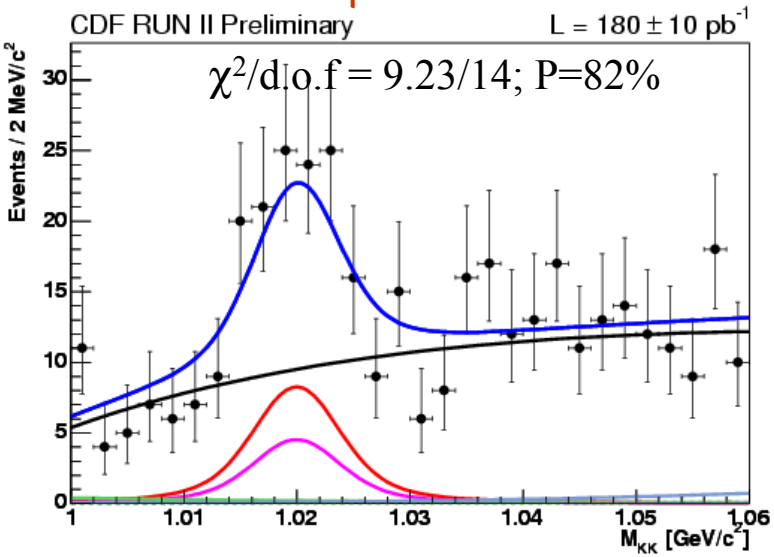
$B_u \rightarrow \phi K^{\pm}$ Fit Results

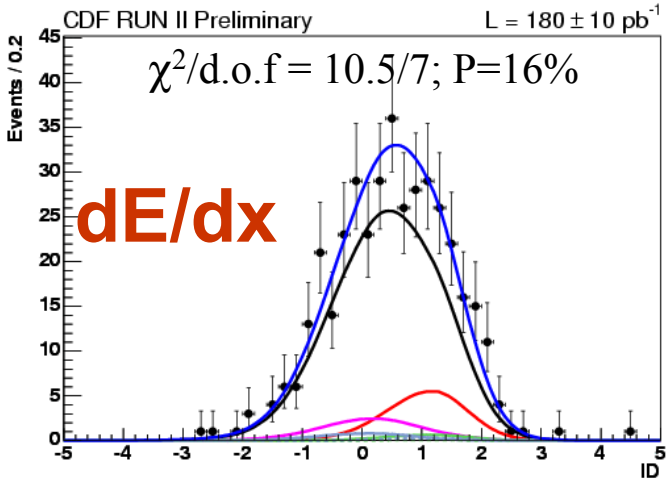
- Total PDF
- Signal
- Partially recon. decays
- comb. bkg

- $B \rightarrow f^0 K$
- $B \rightarrow KKK$
- $B \rightarrow K^{*0}\pi$
- $B \rightarrow K\pi\pi$



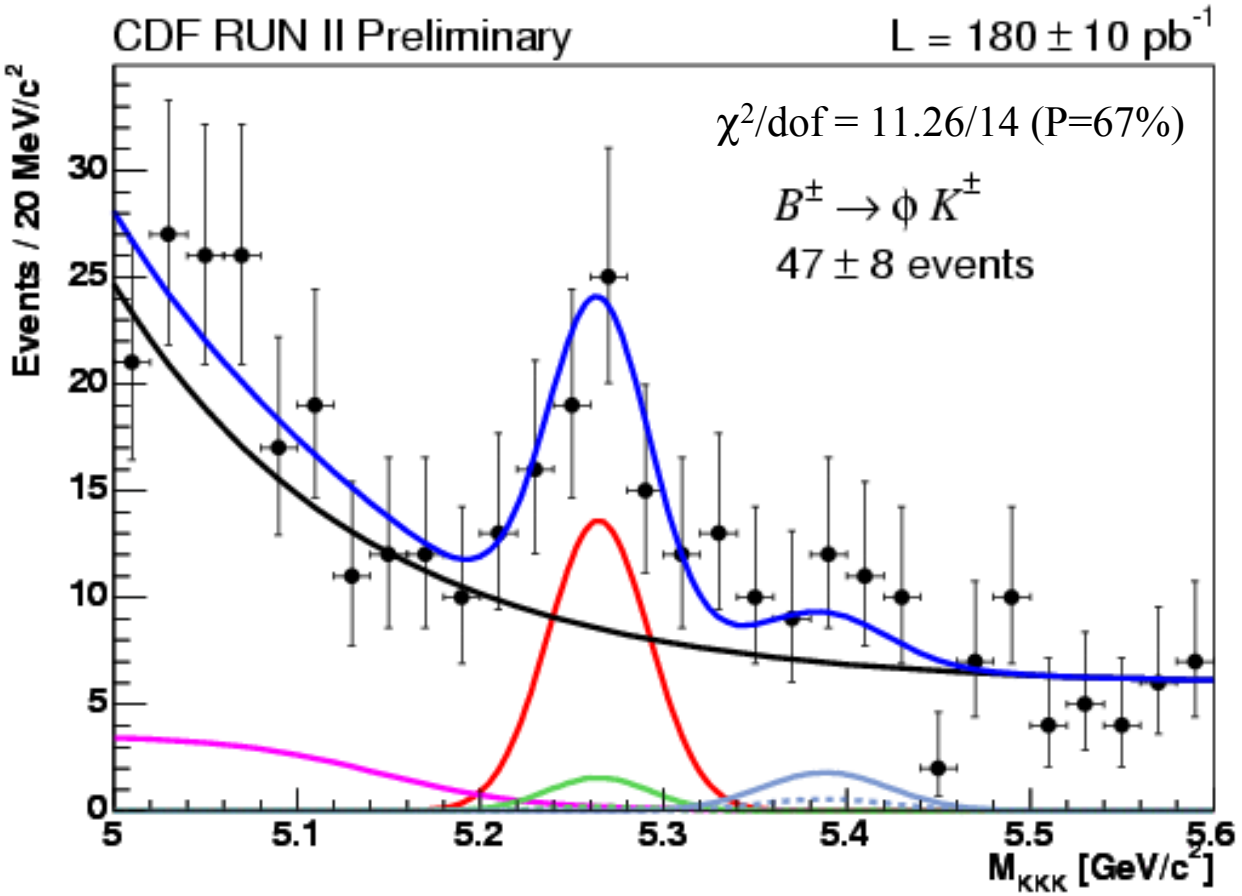
ϕ Mass





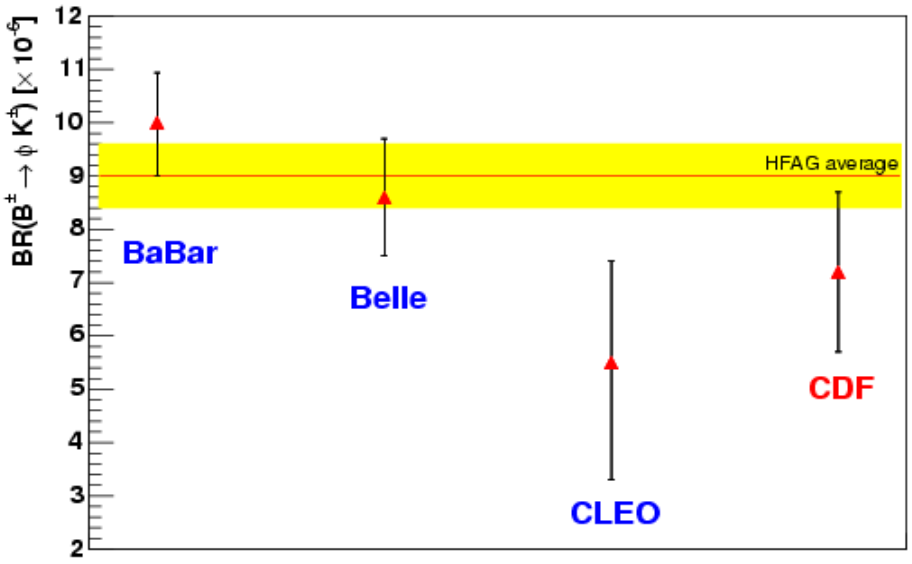
$B_u \rightarrow \phi K^{\pm}$ Signal

- Total PDF
- Signal
- Partially recon. decays
- comb. bkg
- $B \rightarrow f^0 K$
- $B \rightarrow KKK$
- $B \rightarrow K^{*0}\pi$
- $B \rightarrow K\pi\pi$



$B_u \rightarrow \phi K^{\pm}$ Branching Ratio

- $B_u \rightarrow \phi K^{\pm}$ Yield: 47.0 ± 8.4
- $B_u \rightarrow J/\Psi K^{\pm}$ Yield: 439.0 ± 22.0
- Using PDG value: BR ($B_u \rightarrow J/\Psi K^{\pm}$)
  = (1.00 ± 0.04) x 10^{-3}



Systematics:

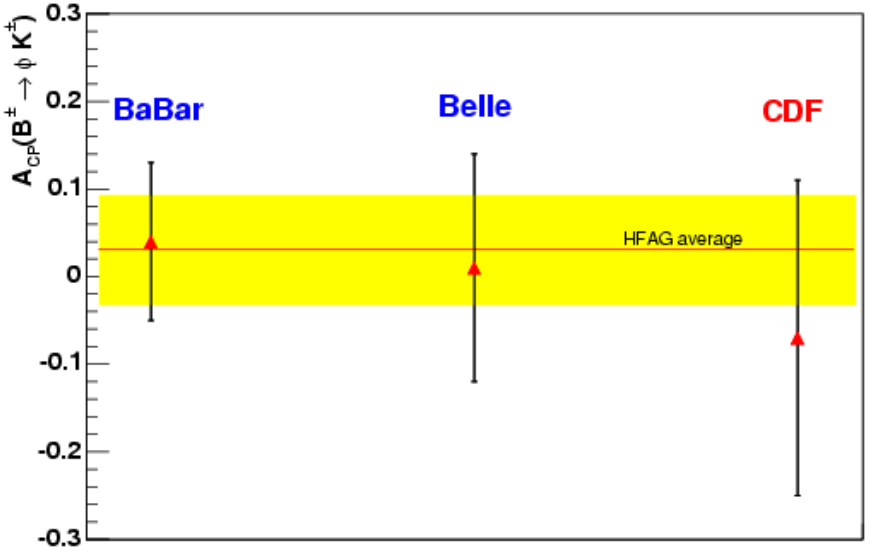
- BR measured w.r.t control channel
  → **Most systematics cancel**
- Dominant contribution from:
  - Particle dependent trig. Eff.: **7.2%**

$$BR(B_u \rightarrow \phi K^{\pm}) = (7.2 \pm 1.3 \pm 0.7) \times 10^{-6}$$

$B_u \rightarrow \phi K^{\pm}$ A_{CP}

Dominant systematics from:

- Detector charge asymmetry: **5%**
- Fit templates & method: **2.5%**



Fit Results:

$A_{CP}(B_u \rightarrow \phi K^{\pm})$: 0.046 ± 0.050

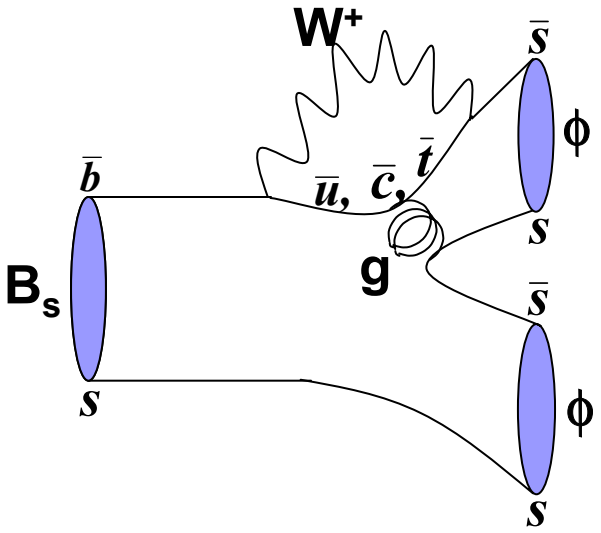
$A_{CP}(B_u \rightarrow J/\psi K^{\pm})$: -0.07 ± 0.17

A_{CP} (HFAG) = 0.03 ± 0.07

$$A_{CP} = \frac{\Gamma_{B^- \rightarrow \phi K^-} - \Gamma_{B^+ \rightarrow \phi K^+}}{\Gamma_{B^- \rightarrow \phi K^-} + \Gamma_{B^+ \rightarrow \phi K^+}} = -0.07 \pm 0.17 \,^{+0.06}_{-0.05}$$

Bs → ϕ ϕ Search

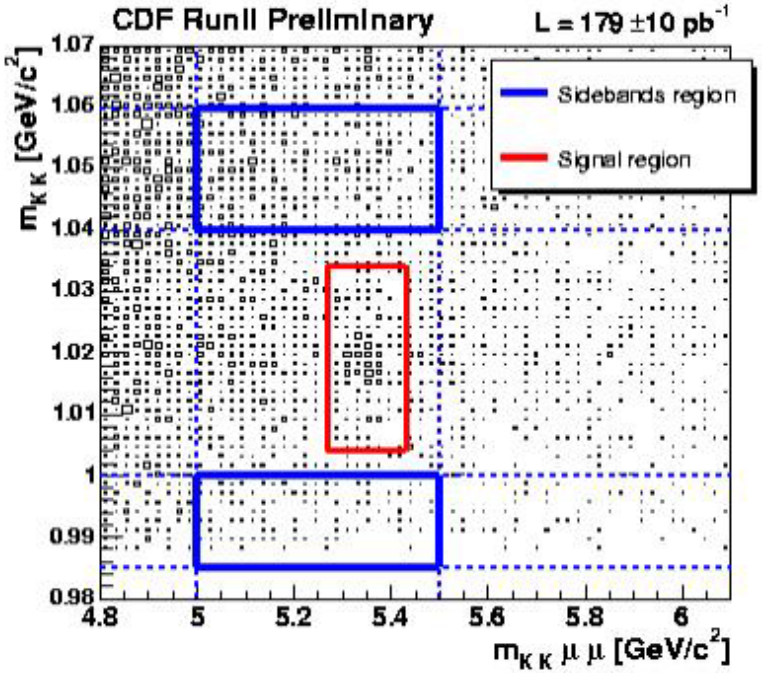
- **Never observed before**
- Bs →V V decay, not a CP eigenstate
- Angular analysis possible in future
- No or very little direct A_{CP} expected in this channel by SM.
- Gluonic penguin → **Probe for New Physics**

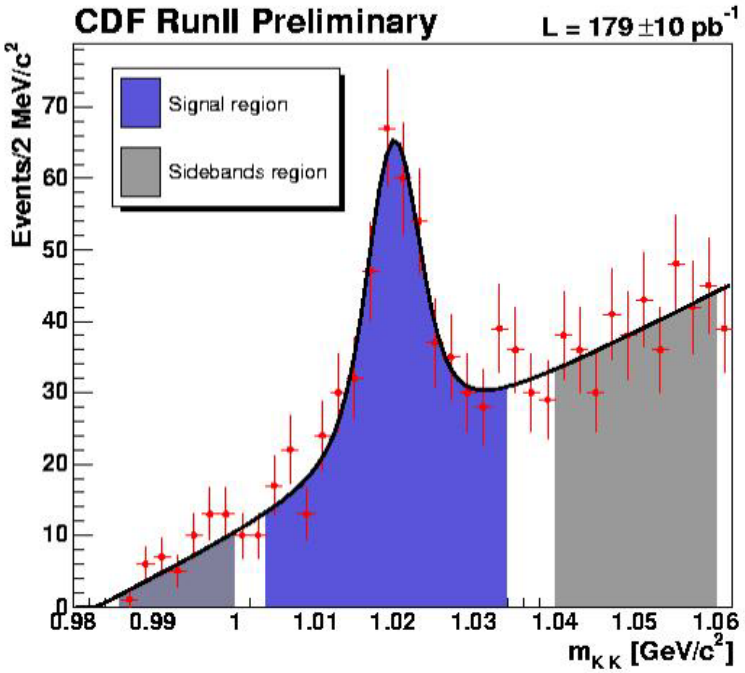


- **Analysis Strategy**:
  - Use high statistics B_d → J/Ψ K^* mode for acceptance corrections and **cut optimization**
  - Use B_s → J/Ψ ϕ as the normalization mode
  - **Cut-based blinded analysis**: Optimize cuts on signal MC and data background
  - Obtain signal distribution → Fit to extract the yields
  - Do separate search in Baseline and Low P_T triggered samples → Merge results

Bs → ϕ ϕ Search

- Optimize cuts on MC sample
  - Projection of transverse decay length Lxy on the B_s P_T direction
  - $P_T(\phi 1)$, $P_T(\phi 2)$, χ^2
  - pointing constraint $d_0(Bs)$
  - impact parameter of reconstructed ϕ





- Maximize the significance variable:

$$\Sigma = \frac{S}{1.5 + \sqrt{B}}$$

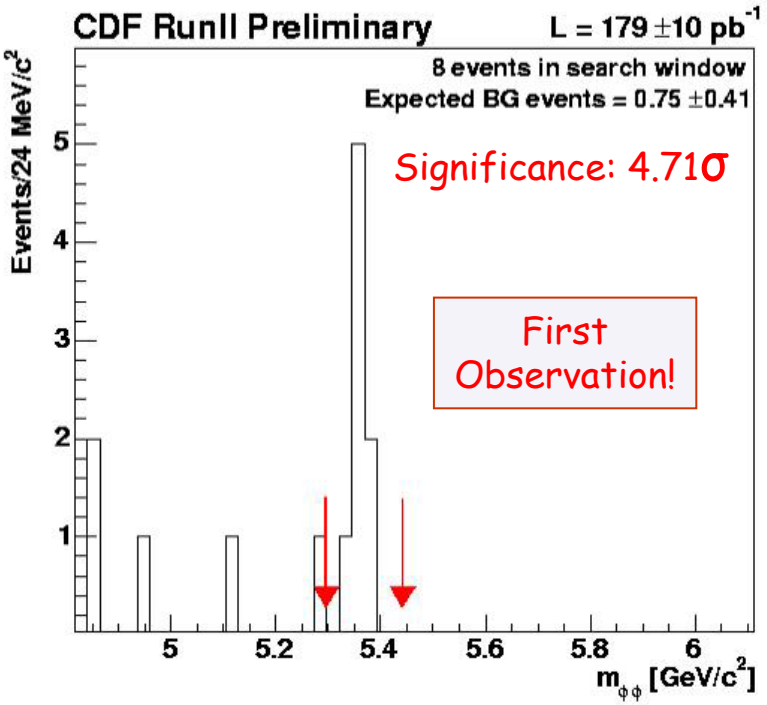
- Optimization independent of MC sample size
- Optimized for 3σ significance.

Bs → ϕ ϕ Results

Optimized cuts:

- $d_0(B_s) < 80\ \mu m$
- $P_t(\phi) > 2.5$ GeV/c
- $L_{xy} > 350\ \mu m$
- $\chi^2_{xy} < 10$

Open the box!



Dominant source of systematics:

- **36%** from BR(Bs → J/Ψ ϕ) [CDF Run 1]

Combined Baseline+LowPt Significance: 4.8σ

From MC

$$BR(B_s \to \varphi\varphi) = \frac{N(B_s \to \varphi\varphi)}{N(B_s \to \psi\varphi)^{corr}} \frac{\varepsilon(\psi\varphi)}{\varepsilon(\varphi\varphi)} \cdot \frac{BR(B_s \to \psi\varphi).BR(J/\psi \to \mu^+\mu^-)}{BR(\varphi \to K^+K^-)}$$

From PDG

BR = (1.4 ± 0.6 ± 0.2 ± 0.5 (BR)) × 10^{-5}

Summary

- CP Asymmetry in hadronic charmless decays measured at CDF , agreement with HFAG, consistent with zero
- New pure penguin decay mode observed for B_s, additional mode for $\Delta\Gamma_s$
- Looking forward to higher luminosity for studying more b → sss decay modes